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Bankruptcy Analysis of Polish Waste Management Companies: Proposal of a Discriminatory model

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Abstract

The waste management system should be constantly monitored to ensure rational waste management, limit the possibility of contamination of surface and groundwater, reduce the risk of waste fires and illegal storage. Unfortunately, in many cases this system remains without constant supervision, and subsequent waste management enterprises remain bankrupt, are closed or are subject to bankruptcy proceedings. Main aim of this paper is the construction of the author's model of financial bankruptcy prediction dedicated to the specificity of waste management companies activity. That discriminatory model will allow entities dealing with waste management to be given early warning of the risk of bankruptcy and for them to take corrective actions that will allow them to continue their very important activities aimed at protecting the natural environment. Based on the backward stepwise regression procedure on a group of 136 bankrupt and 136 still operating enterprises from the analyzed sector of economy, a discriminatory model was proposed. It was able to accurately predict the bankruptcy/continuation of business activity of over 76% of the analyzed waste management enterprises. The effectiveness of the predictions of the original model is much higher than the predictions calculated using other, popular discriminatory models. Obtained research results indicate that the proposed models should be constantly developed for waste management companies, not only for economic reasons, but above all for environmental reasons.

Keywords: bankruptcy, *financial analysis*, *discriminatory models*, *waste management*, *environmental protection*.

JEL classification: C10, C39, Q54

1. Introduction

Municipal solid waste is any substance resulting from human activity that is disposed of and treated as worthless (Abubakar et al., 2022). Disposing of municipal waste by depositing it in landfills is the most popular method (Šourková et al., 2020). The rising costs of waste disposal lead to improper waste management, which in turn may have a negative impact on the soil and water environment (Cirrincione et al., 2022). This

problem concerns not only developing countries, where current municipal waste management procedures, in particular their collection, processing and disposal, are considered ineffective.

The worst situation occurs in the case of uncontrolled landfills, which cause physical and chemical degradation of land. For this reason, landfills are potential and actual sources of pollution. In the world, municipal solid waste is dumped near water bodies, which causes the migration of waste leachates and higher possibility of pollution of the soil and water environment (Ghouti et al., 2021). The composition of municipal waste usually includes heavy metals, persistent organic pollutants, sulfates, chlorides, polycyclic aromatic hydrocarbons from batteries, wood waste and waste electronic equipment (Abul et al., 2010; Yin et al., 2017; Dąbrowska et al., 2023). In 2022, there were 2,301 selective municipal waste collection points in Poland, 1,325 waste collection enterprises and 259 municipal waste landfills (Statistics Poland, 2023). In the same year, 10,714 illegal landfills were closed. Of the waste collected in 2022, over 60% was recovered, of which almost 30% was for recycling, almost 15% for composting, and approximately 20% for thermal transformation.

Sustainable waste management is increasingly being talked about (Hettiarachchi et al., 2018). However, in the context of constant economic development, increased waste production, increasing population and migration of people to cities, this is a huge challenge (Ruggieri et al., 2019). Sustainable waste management requires limited production, waste classification, reuse, recycling and energy recovery instead of traditional storage, operation of open landfills or incineration in a way that does not ensure appropriate safety standards (Khan, 2013; Yang et al., 2018).

The municipal waste management system is divided into collection, transport from collection points and final treatment (Rigamonti et al., 2016). All of these elements should be constantly monitored so that waste management can be considered sustainable (Rodrigues et al., 2021). Unfortunately, in many cases this system remains without constant supervision, and subsequent waste management companies remain bankrupt, are closed or are subject to bankruptcy proceedings. In the waste management sector, government authorities are investing heavily in the so-called circular economy (Luttenberger, 2020). Despite the fact that municipal waste constitutes approximately 10% of all waste, it is necessary to reuse it (Gharfalkar et al., 2015). Companies specializing in the collection, processing and disposal of waste should pay more attention to strive for sustainable waste management, minimizing the negative impact on the environment and economic growth (Abrate et al., 201; Brouwers et al., 2014; Szopik-Depczyńska et al. al., 2021). The proper functioning of the waste management sector not only guarantees the protection of the land and water environment, but also helps in the development of the so-called green and smart cities (Yigitcanlar et al., 2019; Saleem et al., 2020; Obringer and Nateghi, 2021).

The level of efficiency of such companies can be assessed based on available economic data (Mazzi et al., 2016), which can be downloaded from databases such as the EMIS Intelligence (2023). Detailed data analysis allows for early identification or the possibility of reacting in the event of a threat of bankruptcy of an entity, which allows for

counteracting threats related to the loss of sustainable waste management. For this purpose, it is possible to use the so-called discriminatory models.

The development of discriminatory models of early warning of enterprises against bankruptcy was initiated by the work of Edward Altman (1968). The concept of discriminatory models are used for the prediction of the future financial position many types of enterprises (Klimczak, 2007; Antczak, 2015), also those dealing with waste management (Woodard, 2021). Unfortunately, the number of studies is still low, especially in the context of their functioning in the Polish economy. There are no clearly defined variables that (with some degree of probability) could help predict the upcoming bankruptcy of waste management companies. This was the main motivation for the authors to define an original discriminatory model adapted to the nature of the above-mentioned sector, the importance of which becomes invaluable from year to year. Similar procedures can often be found in the literature in relation to various economic sectors in individual countries around the world (Oreski et al., 2012; Pepler et al., 2017; Brusco et al., 2019).

It should be noted that this type of research is becoming more and more popular among researchers. These studies are, for the most part, selective. The analysis may include the size of the enterprise, location, sector of operation or number of employees. Due to the fact that the most frequently used models are not universal (Kitowski 2013; Tomczak, Radosiński, 2017), it turns out that the transferability of Altman's (2005) models to the conditions of the Polish economy cannot be positively confirmed. These models are adapted to different economic sectors (Alaka et al., 2018). Therefore, adaptation of discriminatory models takes place in the industry as well as in the system dimension, defining the general structure of such models, including, for example, the number of analyzed financial indicators (Aziz, Dar, 2006; Czapiewski, 2009; Antonowicz, 2010; Wojnar, 2014; Lichota, 2017; Szewieczek, Lisicki, 2019).

Main aim of this paper is the construction of the author's model of financial bankruptcy prediction dedicated to the specificity of waste management companies activity. The presented model will be verified in terms of its suitability for the risk assessment of the stability of functioning of selected polish companies from the group of waste management enterprises that went bankrupt or were undergoing bankruptcy proceedings in 2013-2022. The results of the model will also be compared with the results obtained by using five selected models, which have been often used in the previous literature. To achieve the main aim of the paper is necessary to provide the main hypothesis of the study. It is following: the discriminatory models used so far do not allow to accurately predict the bankruptcy of enterprises from the waste management sector operating in Poland. Therefore, it is obligatory to prepare an original model that will be dedicated to this group of business entities.

2. Methodology

To achieve the main aim of the paper firstly was necessary to verify the suitability of other, selected (previously used in the research) discriminatory models to predict the bankruptcy of waste management enterprises. Have been chosen the five models, which were following:

- The Altman Z"-score model for emerging markets (Altman, Hotchkiss, 2005),
- The Hadasik's model (Hadasik, 1998),
- "Poznanski" model (Hamrol, Czajka, Piechocki, 2004),
- The Maczynska's model (Mączyńska, 1994),
- The Pogodzinska&Sojak model (Pogodzińska, Sojak, 1995).

It was decided to choose the above-mentioned discriminatory models due to their widespread use and the fact that four of them were created in domestic conditions, which should better reflect the specificity of running a business in Poland (Pawłowski, 2018). The availability of data necessary to calculate discriminatory functions for waste management entities that have gone bankrupt in recent years was also taken into account. For this purpose, the resources of the EMIS Intelligence database (2023) were used, which is an economics database containing detailed information on, among others, companies and economic sectors from over 197 emerging markets.

Each of the above models is based on a different discriminatory function and its limit values, which are intended to separate enterprises at risk of bankruptcy from those whose financial condition is unquestionable. Therefore, it seems necessary to present the general patterns of each of them.

Each of the discriminatory models presented above has been used to theoretically predict the bankruptcy of waste management companies in Poland. The intention of such a procedure was to verify the possibility of using one of the studied models to potentially predict the bankruptcy of entities operating in this sector (Lisicki, Świeboda, 2023).

For this purpose, it was necessary to obtain numerical data contained in the financial statements of entities classified in the indicated industry. The resources of the above-mentioned EMIS Intelligence database were used for this purpose. Using the Company Screener, have been found unlisted companies operating on the Polish market whose dominant activity was focused on waste management (they were included in the E-WATER SUPPLY; SEWAGE AND WASTE MANAGEMENT AND ACTIVITIES RELATED TO REMEDIATION Polish Classification of Activities (PKD, 2007) sectors and which were closed, liquidated or were undergoing bankruptcy proceedings. Due to the limitations of the database, data from the financial statements of entities from 2013-2022 were used. What is worth emphasizing, to calculate the value of the discriminatory functions of the five models presented earlier, each time data from the last available financial statements before the announcement of liquidation (commencement of bankruptcy proceedings) were used.

Based on the indicated assumptions, data was collected from 612 entities classified in sector E of the Polish Classification of Activities (2007), which went bankrupt (or were undergoing bankruptcy proceedings) in the years 2013-2022. While analyzing the data of the indicated entities, it was noticed that there were deficiencies in the data of some entities that would make it impossible to calculate the value of the discriminatory functions of the indicated bankruptcy models. Ultimately, 136 waste management companies were included in the research sample.

To ensure comparability, the same number of enterprises from the analyzed sector (randomly selected with similar size and legal form) that were characterized by good financial condition were also qualified for the study. Their last available financial report was used, which in the vast majority of cases was the report for 2022. Finally, the values of the discriminatory function were calculated for 272 waste management companies in Poland using each of the discriminatory models presented above.

These calculations were intended to indicate the level of accuracy of forecasts of failure/prosperity of the surveyed enterprises using selected discriminatory models. However, assuming in the main hypothesis of this study the low predictive capacity of the indicated models, it was necessary to propose an original discriminatory model that would reflect the specificity of the activities of waste management companies and which would, to a greater extent, allow for earlier detection of possible symptoms of bankruptcy risk. This model will be constructed by using the backward stepwise regression (backward elimination) method. The use of model construction for regression with a single dependent variable explained by a set of independent variables has already been described in many works, not only from the areas of economics and management (Lindeman, Merenda, Gold, 1980; Younger, 1985; Stanisz, 2007; Kosmala, 2012).

This method is a variant of regression analysis in which only statistically significant predictors (explanatory variables) are introduced into the model. They are intended to determine the level of the explained variable in the best possible way. According to its procedure, it is necessary to carry out several basic stages of the procedure (Juszczyk, Balina. 2009), which include:

- identifying the initial model (multiple regression),
- using a "stepwise" procedure, i.e. changing the initial model (in subsequent steps of the previous model) by removing the predictor with the lowest statistical significance,
- ending the procedure when all explanatory variables of the model show statistical significance at the adopted p-value level (e.g. $p<0.05$).

To construct this model a set of 21 basic financial indicators have been used (Table 1). This group consists of ratios included in abovementioned discriminatory models and other indicator, which have been the most often mentioned in the polish literature (Tłuczak, 2013; Wojnar, 2014; Pitera, 2021, Kitowski, 2021).

Table 1: List of explanatory (X) variables used in the backward stepwise regression model to explain the threat of bankruptcy (Y variable) in the selected waste management enterprises

	Indicator (Explanatory (X) variable)	Formula
X_1	Share of net profit in EBIT	Net profit/EBIT
X_2	Operational rent of assets	EBIT/Total assets
X_3	Current ratio-CR	Current assets/Current liabilities
X_4	Working capital ratio	Working capital/Total assets
X_5	Quick ratio-QR	(Current assets-inventories)/Current liabilities
X_6	Total debt to assets ratio	Total liabilities/Total assets

X_7	Service of a debt ratio	(Gross profit + amortization&depreciation)/Total liabilities
X_8	Equity ratio	Equity/Total assets
X_9	Total assets turnover-TAT	Net sales revenue/Total assets
X_{10}	Days sales outstanding-DSO	Receivables*365/Net sales revenue
X_{11}	Inventory turnover ratio	Inventories*365/Net sales revenue
X_{12}	RE/TA	Retained earnings/Total assets
X_{13}	Debt to equity-D/E (inverse)	Equity/Total liabilities
X_{14}	Rent of assets-ROA	Net financial result/Total assets
X_{15}	Share of longterm capital in total assets	Equity&longterm liabilities/Total assets
X_{16}	Share of net sales result in net sales revenue	Net sales result/ Net sales revenue
X_{17}	Rent of sales-ROS	Net financial result/ Net sales revenue
X_{18}	Gross rent of sales	Gross sales result/ Net sales revenue
X_{19}	Share of current assets in total liabilities	Current assets/Total liabilities
X_{20}	Cash flow to assets-CF/A	Operating cash flows/Total assets

Source: own study based on the literature review (Mączyńska, 1994; Pogodzińska, Sojak, 1995; Hadasik, 1998; Hamrol, Czajka, Piechocki, 2004; Altman, Hotchkiss, 2005; Tłuczak, 2013; Wojnar, 2014; Pitera, 2021).

Based on the backward stepwise regression firstly is necessary to verify which of proposed indicators (model explanatory variables-X) would allow in the most accurate way to predict the bankruptcy/continuation of business activity (explained variable-Y) of the waste management enterprises. In order to construct an appropriate discriminatory model, it was mandatory to process a quantitative quantification of the qualitative Y variable. In this area, authors assigned a value 0 of the discriminatory function for the bankrupt and 1 for the operating entities (Juszczyk & Balina, 2009).

The first step in this research procedure was the elimination of highly correlated variables with Pearson's correlation coefficient (R) between <0,7-1> and <-1, -0,7> (Immink, Weber, 2014). Then, using the method of least squares, the linear regression coefficients of the discriminatory function were calculated. Next parts was rejection of those variables whose statistical significance was the lowest. It has been continued until all variables in the regression model were statistically significant (at least $p<0.05$). After the evaluation of the statistically significant variables to the models and calculation of their regression coefficient were set critical value of the discriminatory function. If a model value for the waste management enterprises would be lower than critical value, it is possible to think that entity would go bankrupt in the near future.

3. Results and discussion

In the first stage of this part of the paper the authors used the five abovementioned models to assess the utilization of these models in the group of waste management enterprises. For this purpose, it was necessary to calculate the presented discriminatory functions for each of the 272 waste management enterprises included in the research sample. As a

reminder, it should be noted that 136 of them of them declared bankruptcy or are undergoing bankruptcy proceedings (in the research period 2013-2022), while the same number were companies still functioning on the Polish market. A comparison of forecasts of these models is presented in table 2.

Table 2: Number of waste management enterprises qualified to categories in selected discriminatory functions

Model/Group of enterprises (n=272)		Threatened with bankruptcy	Transition zone	No symptoms of bankruptcy	Share of incorrect forecast (%)	Mean forecast error (%)
Altman EMS	Banrkrupts (n=136)	48	19	69	50,74	41,92
	Operating enterprises (n=136)	45	22	69	33,09	
Hadasik	Banrkrupts (n=136)	33	-	103	75,74	42,28
	Operating enterprises (n=136)	12	-	124	8,82	
Poznanski	Banrkrupts (n=136)	44	-	92	67,65	38,61
	Operating enterprises (n=136)	13	-	123	9,56	
Maczynska	Banrkrupts (n=136)	61	16	59	55,15	41,55
	Operating enterprises (n=136)	38	41	51	27,94	
Pogodzinska&Sojak	Banrkrupts (n=136)	10	9	117	86,03	43,39
	Operating enterprises (n=136)	1	0	135	0,74	

Source: own calculations.

Effectiveness of bankruptcy forecasting in the group of the selected 272 enterprises (136 bankrupts and 136 well-functioning enterprises) in the indicated models was low. The average error in the accuracy of the forecast of the financial condition of waste management enterprises in Poland was approximately 40%. This means that the continuation of the activities of the analyzed entities (or lack thereof) was not accurately predicted in the case of 4 out of 10 enterprises. Moreover, when attention is focused solely on business entities that have declared bankruptcy, this percentage is much higher. The Pogodzińska&Sojak model was the most ineffective (86.03%), which was one of the first discriminatory models in Poland (Pogodzińska, Sojak, 1995). The simplicity of its

calculations and the small research sample for which it was verified prove that its wider use is not possible. A similarly high ineffectiveness of forecasts (75.74%) for bankrupt companies can be noted in the case of the Hadasik model (1998) and the Poznański model (67.65%). Both of these models were more extensive than the first model mentioned above and were created on the basis of Polish entities from various sectors of the economy. However, this did not help in achieving a high predictive capacity for bankruptcy of waste management companies. Somewhat surprising is the highest accuracy (less than 50%) of the Altman model for emerging markets - Altman ZEMS (Altman, Hotchkiss, 2005), which was created for a wide group of emerging markets, and not only the Polish market. Its higher (compared to the other studied models) predictive abilities confirm that the presented structure and its wide application in global research are justified (Berzkalne, Zelgalve, 2013; Mosionek-Schweda, 2014; Almamy, Aston, Ngwa, 2016).

Significantly lower forecast accuracy errors were recorded in the case of entities that are still operating (not bankrupt). However, the assumption of discriminatory models was primarily to predict the possible bankruptcy of business entities (Antczak, 2015; Pepler, Uys, Nel, 2017), therefore the lack of effectiveness of forecasts in relation to the studied waste management companies is significant.

The above results indicate the existence of insufficient predictive power of these bankruptcy models for waste management enterprises. The situation was an inspiration for the authors to create a new discriminatory model dedicated to waste management enterprises functioning in Poland.

For preliminary calculations, the financial indicators presented in the previous part of the paper were selected. They were used in previous discriminatory models or were indicated in the literature as the most frequently used to conduct discriminatory analysis of enterprises (Tłuczak, 2013; Wojnar, 2014; Pitera, 2021, Kitowski, 2021). In the case of companies that declared bankruptcy, the ratios were determined on the basis of financial statements for the last full financial year before the declaration of bankruptcy. In the case of companies that continuously conducted business activities, these indicators were determined for financial statements including financial data for 2022.

In the process of the new discriminator model construction (dedicated for the waste management enterprises), the first step was the removal of explanatory (X) variables (from the above-mentioned 20 indicators) highly correlated with each other. For the purposes of the study, it was assumed that the absolute value of the Pearson's correlation coefficient (R) of 0.7 would be the limit level indicating high autocorrelation of the explanatory variables (Juszczyk, Balina, 2009; Immink, Weber, 2014). The selection of explanatory (X) variables that were highly correlated with each other, which should be rejected before starting the backward stepwise regression procedure, made it possible to prepare a correlation matrix. It is presented in table 3.

Table 3: Correlation matrix of explanatory variables used to preparation a discriminatory model for waste management enterprises

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1	0,64	0,00	-0,07	0,00	0,07	0,72	-0,07	-0,01	0,00
X_2	0,64	1	0,04	0,01	0,03	0,00	0,94	0,00	-0,01	-0,06
X_3	0,00	0,04	1	0,15	0,98	-0,12	0,13	0,12	-0,04	-0,04
X_4	-0,07	0,01	0,15	1	0,13	-0,98	-0,03	0,98	-0,79	-0,02
X_5	0,00	0,03	0,98	0,13	1	-0,11	0,12	0,11	-0,03	-0,03
X_6	0,07	0,00	-0,12	-0,98	-0,11	1	0,03	-1,00	0,84	0,01
X_7	0,72	0,94	0,13	-0,03	0,12	0,03	1	-0,03	-0,03	-0,04
X_8	-0,07	0,00	0,12	0,98	0,11	-1,00	-0,03	1	-0,84	-0,01
X_9	-0,01	-0,01	-0,04	-0,79	-0,03	0,84	-0,03	-0,84	1	-0,04
X_{10}	0,00	-0,06	-0,04	-0,02	-0,03	0,01	-0,04	-0,01	-0,04	1
	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
X_{11}	1	0,04	-0,05	-0,05	-0,01	-0,02	0,00	-0,01	-0,04	-0,10
X_{12}	0,04	1	0,05	-0,99	0,16	0,02	0,99	0,99	0,03	0,04
X_{13}	-0,05	0,05	1	-0,04	0,16	-0,04	0,05	0,05	0,87	-0,05
X_{14}	-0,05	-0,99	-0,04	1	-0,05	-0,02	-1,00	-0,99	-0,02	-0,02
X_{15}	-0,01	0,16	0,16	-0,05	1	-0,35	0,07	0,07	0,11	0,05
X_{16}	-0,02	0,02	-0,04	-0,02	-0,35	1	0,03	0,03	-0,01	-0,03
X_{17}	0,00	0,99	0,05	-1,00	0,07	0,03	1	1,00	0,03	0,05
X_{18}	-0,01	0,99	0,05	-0,99	0,07	0,03	1,00	1	0,03	0,05
X_{19}	-0,04	0,03	0,87	-0,02	0,11	-0,01	0,03	0,03	1	-0,04
X_{20}	-0,10	0,04	-0,05	-0,02	0,05	-0,03	0,05	0,05	-0,04	1

Source: own calculations.

Based on above correlation matrix variables X3, X4,X6,X7,X8, X12, X13, X14, X15, X17, X18 and X19, which show strong interdependence, were excluded from further calculations. From the remaining 8 explanatory (X) variables (X1, X2, X5, X9, X10, X11, X16 and X20) the authors created a linear regression model. Like mentioned, it was assumed that explained (Y) variable would be assigned a function value of 0, when the company declared bankruptcy, or to be assigned the value of 1, when the enterprise continued their business activity. Values of regression coefficients for particular variables at the initial stage of the research have been presented in the table 4. It includes also their statistical significance estimated using the t test.

Table 4: Correlation matrix of explanatory variables used to preparation a discriminatory model for waste management enterprises

Explanatory (X) variable	Regression coefficient	t-test value
X_1	-0,04258	-1,89624
X_2	0,05259	0,68472
X_5	-0,02016	-2,43936
X_9	-0,00468	-1,43503
X_{10}	-0,00004	-0,59853
X_{11}	-0,00002	-0,84307
X_{16}	0,00000	-1,00030
X_{20}	0,73090	3,32856
Interception	0,53429	12,52639

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Source: own calculations.

Based on the presented in the Table 4 initial model was possible to start the backward stepwise regression procedure. Observation of the *t* test statistics of the obtained coefficients indicates that not all of them are statistically significant (at least $p<0,05$). Therefore, in the next step of the research, it was decided to reject the variable with the lowest value of the *t* test statistic. It was variable X10. Continuing the backward stepwise regression procedure in the next steps have been rejected the following variables (in the given order): X_2, X_{16}, X_{11}, X_9.

Finally, to the discriminatory models of the waste management enterprises in Poland have been chosen following variables: X_1, X_5, X_{20}. All of them were statistically significant (at least $p<0,05$). The final form of the discriminatory function of the developed regression is as follows in below formula:

$$DL= 0,5-0,0317X_1-0,0187X_5+0,8217X_{20}$$

where:
X_1 – Share of net profit in EBIT: Net profit/EBIT
X_5 – QR:(Current assets-inventories)/Current liabilities
X_{20} –CF/A: Operating cash flows/Total assets

In the next stage of considerations on the construction of a discriminatory analysis model for the waste management enterprises, it was necessary to estimate the critical value that the value of the estimated DL function. It value helps to distinguish enterprises which may be at risk of bankruptcy and which are likely to still running their business activity. Due to the assumption that the value of the discriminatory function equal to 0 was assigned to the bankrupt waste management enterprise, and the value of the discriminatory function equal to 1 was assigned to the enterprise continuing its business activity, the natural limit of the critical value separating bankruptcy from the good financial condition of waste management enterprises should be considered 0.5 (Szewieczek, Lisicki, 2019). Analyzing the obtained results, it was found that the critical value in this model should be 0.48, because allows for slightly better accuracy of bankruptcy forecasts of enterprises from the analyzed industry than the value of 0.5.

Therefore, the authors propose a division of analyzed enetrprises as follows:

- I group “Prospective”- value of the discriminatory function is ≥0.48. The entity is at low risk of bankruptcy in the near future.
- II group “Threatened”- value of the discriminatory function is <0.48. The entity is at a high risk of bankruptcy.

Last step of the backward stepwise regression procedure was to verify the effectiveness of the proposed model on the example of 272 waste management enterprises, half of which declared bankruptcy. The proposed 0.48 critical value correctly forecasted the bankruptcy in the 107 out of 136 “Threatened” enterprises (78,68% accurate forecast). Simultaneously, among enterprises “Prospective”, the accuracy of the business continuity forecast was noticed for 101 out of 135 entities (74,26% accurate forecast). The research results indicate that the proposed regression model was characterized by a much higher effectiveness in predicting bankruptcy (continuation of business) of waste management

companies than 5 generally available, well-known discriminatory models: Altman Z"-score model for emerging markets (Altman, Hotchkiss, 2005), Hadasik's model (Hadasik, 1998), "Poznanski" model (Hamrol, Czajka, Piechocki, 2004), Maczynska's model (Mączyńska, 1994) and Pogodzinska&Sojak model (Pogodzińska, Sojak, 1995).

These results confirm previous observations by researchers (Pacey, Pham, 1990; Talebnia, Karmozi, Rahimi, 2016) regarding the lack of universality of the discriminatory models used. Their use should take into account the specificity of the industry for which the discriminatory analysis is conducted (Grice, Ingram, 2001; Ho et. al., 2013; Adamowicz, Noga, 2017) and the size of the surveyed enterprises (Dolejšová, 2015; Langabeer et. al., 2018) or the market in which they operate (Mosionek-Schweda, 2014; Rybárová, Braunová, Jantošová, 2016). Therefore, the hypothesis proposed at the beginning of the study seems to have been positively verified. Commonly used discriminatory models do not allow to accurately predict the bankruptcy of enterprises from the waste management sector operating in Poland. Better accuracy of forecasts is provided by an original model prepared using (e.g.) backward stepwise regression. This therefore provides a basis for undertaking similar procedure when undertaking discriminatory analysis of enterprises operating in other sectors of the economy or on other markets. That is also why it is necessary to continue scientific research related to the construction of models enabling accurate evaluation of the financial condition of businesses (Tomczak, Radosiński, 2017).

4. Conclusions

Any economic activity, even those related to waste disposal, leads to the production of waste. Waste poses a real threat to the soil and water environment. Statistical data (Eurostat, 2020) show that in 2020 alone, industrial enterprises generated 48.2% of all hazardous and non-hazardous waste. The level of waste produced by companies involved in water supply, wastewater management, transport and waste treatment is increasing. Landfilling is still the most common waste management method in the European Union, despite the fact that the amount of waste going to landfills is constantly decreasing. The waste contains, among others, heavy metals, persistent organic pollutants, sulfates, chlorides, polycyclic aromatic hydrocarbons. Lack of control over waste management poses a threat to groundwater, especially in the case of landfill fires, which additionally generate pollutants released into the atmosphere, such as carbon monoxide and dioxide, nitrogen oxides, hydrochloric acid, hydrogen cyanide, volatile organic compounds, persistent organic pollutants, ketones and aldehydes. Controlling the functioning of these companies is extremely important because it guarantees proper waste management, limiting the amount of waste stored, limiting the possibility of migration of pollutants, and carrying out activities supporting the monitoring of water quality (Morello et al., 2018; Yang et al., 2018; Kwenda et al., 2022).

All of these elements should be constantly monitored so that waste management can be considered sustainable (Rodrigues et al., 2021). Unfortunately, in many cases this system remains without constant supervision, and subsequent waste management companies remain bankrupt, are closed or are subject to bankruptcy proceedings.

The level of efficiency of such companies can be assessed based on available economic data (Mazzi et al., 2016). Detailed data analysis allows for early identification or the

possibility of reacting in the event of a threat of bankruptcy of that entity, which allows for counteracting threats related to the loss of sustainable waste management. For this purpose, it is possible to use the so-called discriminatory models, which were the main subject of this paper.

Main aim of this paper was the construction of the author's model of financial bankruptcy prediction dedicated to the specificity of waste management companies activity. The main hypothesis accompanying the purpose of the paper indicated that, discriminatory models used so far do not allow to accurately predict the bankruptcy of enterprises from the waste management sector operating in Poland. Therefore, it is obligatory to prepare an original model that will be dedicated to this group of business entities.

At the beginning of the paper's empirical part, the accuracy of bankruptcy forecasts of waste management companies was verified using 5 popular discriminatory models: Altman Z"-score model for emerging markets, Hadasik's , "Poznanski", Maczynska's and Pogodzinska&Sojak. 136 waste management enterprises that declared bankruptcy in 2013-2022 and the same number of enterprises that were still running their business activities were selected for analysis. As could be expected based on previous research on the use of discriminatory models (e.g. Aziz, Dar, 2006; Tomczak, 2017; Adamowicz, Noga, 2017), publicly available models did not reflect high accuracy of bankruptcy/continuation business activity in forecasts of waste management enterprises. The mean forecast error exceeded 40%, which meant that in the case of 4 out of 10 surveyed enterprises, forecasts using the indicated discriminatory models were inaccurate. It was necessary to prepare a model that would be adapted to the specific activities of waste management companies.

For this purpose, backward stepwise regression methodology has been used. After carrying out all the necessary steps of the procedure, a discriminatory model was developed, which allows separating enterprises from the analyzed industry at risk of bankruptcy from those that are not at risk of bankruptcy with an average efficiency exceeding 76%. Therefore, it is much higher than in relation to the previous discriminatory models presented. Obtained results confirm previous observations by researchers (Pacey, Pham, 1990; Grice, Ingram, 2001; Ho et. al., 2013; Talebnia, Karmozi, Rahimi, 2016) regarding the lack of universality of the discriminatory models used. Therefore, the hypothesis proposed at the beginning of the study seems to have been positively verified. Commonly used discriminatory models do not allow to accurately predict the bankruptcy of enterprises from the waste management sector operating in Poland.

The results obtained in this study allow to draw attention to the problem of using general discriminatory models in predicting the bankruptcy of companies from various industries or markets. According to the authors, such behavior is inappropriate and requires the creation of appropriate models taking into account the specificity of the examined enterprises, such as the industry sector, country of operation or company size (Talebnia, Karmozi, Rahimi, 2016; Langabeer et. al., 2018). Nevertheless, the authors encountered certain limitations in the study, primarily the low percentage of bankrupt enterprises from 2013-2022 that had a full range of data allowing for the calculation of financial indicators used in the models. Ultimately, only 136 out of 612 bankrupt entities were qualified for the research sample. Therefore, it seems necessary to repeat the procedure

for waste management companies in other countries, which will allow for authentication of the research results obtained in this study.

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